A. Residual Stress Measurement in Friction Stir Welded Ti-6Al-4V

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Introduction

Titanium alloys, such as Ti-6Al-4V, are widely used in aerospace, power generation and chemical processing applications owing to their high strength-to-weight ratio and good corrosion resistance in many environments. Welding is an effective manufacturing method for joining components to produce useful components and structures. However, the transient weld thermal cycle often results in the development of residual stresses in the weldment. The presence of the residual stresses can impact subsequent mechanical and corrosion properties of the weldment. The goal of this work was to determine the longitudinal residual stress distribution in a friction stir weld on Ti-6Al-4V and to compare the stress distribution to the microstructures of the various weld zones.

Technical Approach

A cross-sectional map of residual stresses in a section transverse to the weld was measured using the contour method (Ref. 1). The specimen was carefully cut using wire electric discharge machining with a 50-micron diameter wire causing the residual stresses normal to the cut plane to relax. The contour of the cut surfaces was measured by scanning with a confocal laser ranging probe. The deviation of the surface contours from planarity was assumed to be caused by elastic relaxation of the residual stresses and was used to calculate the original residual stresses. The residual stresses were determined from the measured contours using a 3-D elastic finite element (FE) model. The result was a full map over a transverse cross-section of the stress component in the welding direction. Microstructures of the same section were characterized using optical microscopy. The microhardness of the various weld regions was also determined.

Results and Discussion

The distribution of longitudinal residual stress is shown in Figure 1. The stresses were more similar to fusion welding stresses than to the typical two-peak stress distribution reported for FSW in Al alloys (Ref. 2,3). The stir zone or nugget exhibited residual tensile stress. A single peak of tensile stresses exceeding 400 MPa was observed slightly below the surface corresponding to the shoulder of the tool. The stresses were asymmetric with higher stresses on the advancing side of the weld. The high compressive stresses seen at the edge of the plate on the advancing side were likely anomalous and probably arose from machining of the original plates. Contrary to FSWs in Al alloys, microhardness data showed an increase in hardness in the HDAZ/HAZ. The difference in residual stress distribution in the current weld and that in Al alloys may arise from the difference in metallurgical response to the FSW thermomechanical cycle.

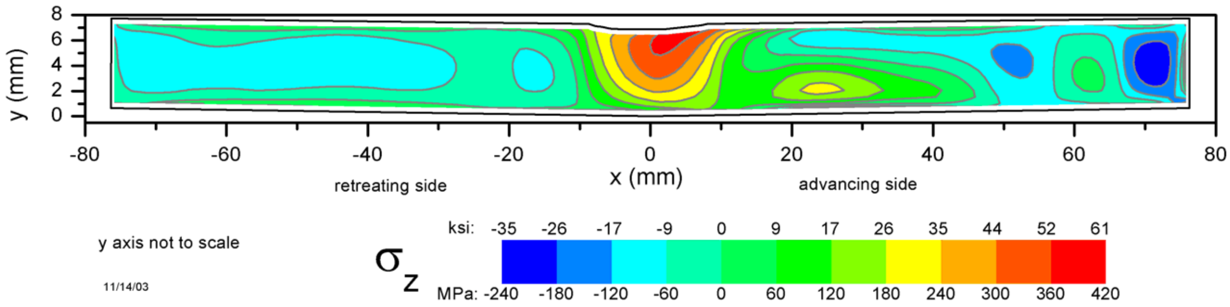

Figure 1: Longitudinal residual stress distribution in a FSW on Ti-6Al-4V using the contour method.

Conclusions

The longitudinal residual stress distribution in a friction stir weld on Ti-6Al-4V was measured using the contour method. The stir zone or nugget exhibited residual tensile stress. A single peak of tensile stresses exceeding 400 MPa was observed slightly below the surface corresponding to the shoulder of the tool. The stresses were asymmetric with higher stresses on the advancing side of the weld.

References

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